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METHODS OF TEACHING ENGINEERING SUBJECTS

BY

JOHN JEFFERSON RICHEY
B. S. UNIVERSITY OF ILLINOIS, 1903

THESIS

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May 1, 1910

I hereby recommend that the thesis prepared under my personal direction by JOHN JEFFERSON RICHEY entitled Methods of Teaching Engineering Subjects be approved as fulfilling this part of the requirements for the degree of Civil Engineer.

Ira O. Baker.
Head of Department of Civil Engineering

Recommendation concurred in:

Ira O. Baker
A N Talbot
Arthur Stock

Committee on Final Examination.

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METHODS OF TEACHING ENGINEERING SUBJECTS.

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I. GENERAL INTRODUCTION.

A large part of the instruction in the colleges of engineering of this country is given by young men. Most of these young instructors have had a year or two of professional experience, although some of them begin teaching only a few months after completing their undergraduate work. In either case, it seldom happens that any of them have chosen teaching for a career or have ever contemplated doing any teaching work, and consequently they have obtained no training designed especially to fit them to become teachers. They have attended engineering schools to secure the training which will enable them to become practitioners of engineering, not teachers of engineering subjects. As the time for graduation and the securing of positions draws near, a few for the first time begin to think of engaging in teaching for a time, when some particular opening comes to their notice. If they secure appointment they inform themselves more fully upon the subjects which they are to teach, but there all special preparation usually ends. Others, after several years of professional experience, are induced to take up teaching for a time, but usually they do not intend to continue in it very long. Thus it happens that much of the teaching in our colleges of engineering is done by young men who have had no training in methods of teaching. Men trained in teaching methods as well as in engineering methods are not to be had, so the young engineer must be depended upon to do the teaching.

It is not to be thought that the engineer's training, both in the technical school and in the professional field, is such as to unfit him for teaching. Quite the contrary is true in fact, as is

evidenced by the fairly efficient instruction which usually prevails in the engineering schools. It is not surprising, however, that the inexperienced instructor, relying for his methods upon his own judgment or upon his memory of the methods used by his own teachers, should fail to become as efficient in his work as he might be and ought to be. He is likely to have too narrow a view as to the purpose of an engineering education, and is almost certain to overlook some of the best methods of teaching, if indeed he does not make use of some which are positively bad. In order that the instruction may be good and that it may be held in proper esteem by the students, a good theoretical knowledge of the subject to be taught and some experience in the practice of engineering are necessary, but just as important is the ability to impart knowledge and to train minds. This ability is by no means to be taken for granted merely because the knowledge and experience are possessed. It is to a large extent a native talent, but much of it can be acquired by a careful study of the best methods of teaching as they have been determined by experience.

After several years the teacher will have perceived some of his mistakes and will have learned better methods by experience and by association with other teachers. However, since so much of the instruction is given by men who remain in that work only a few years, there is a great loss of efficiency on account of the fact that the new instructors do not learn as much of the theory and practice of teaching as they should at the very beginning. It is not that they are unwilling to learn but that they are diffident about asking questions and that they do not know where to find in simple and compact form the help which they need. A brief presentation of the

methods in use in teaching engineering subjects, with some discussion of the merits of these methods, should be helpful to all such inexperienced instructors and may not be entirely lacking in interest to some who are not inexperienced. The time will doubtless come when provision will be made for training young men for the profession of teaching engineering, but until that time comes, the young engineer who takes up teaching can not do better than to learn what methods have been found best in the experience of those who have gone before him.

II. THE PURPOSE OF AN ENGINEERING EDUCATION.

Before an intelligent consideration of the merits of the various methods used in teaching engineering subjects can be had, there must be a clear conception of the purpose of an engineering education. The three definitions quoted below give as good an idea of what constitutes education as can well be briefly stated. "Education in a broad sense, comprehends all that disciplines and enlightens the understanding, corrects the temper, cultivates the taste, and forms the manners and habits." "Intellectual education comprehends the means by which the powers of the understanding are developed and improved, and knowledge is imparted." "Technical education is intended to train persons in the arts and sciences that underlie the practice of the trades or professions." Engineering education includes much more than knowledge of the facts and methods of engineering. Its predominating features should be development of the powers of the understanding and training in the sciences which underlie engineering practice. It is very generally accepted that in dealing with the undergraduate, it is education upon which the emphasis should be laid, rather than upon engineering. The student is to be educated in order that he may readily become an engineer. Some of the teaching that is done, however, seems to be based upon the idea that the technical school should turn out its graduates as engineers, versed in the best practice of the day and skillful in performing various kinds of engineering work. The emphasis is laid upon engineering rather than upon education. This is due largely to the fact that the teaching is done by engineers rather than by educators. Engineers naturally have a tendency to emphasize strongly the importance of engineer-

ing knowledge, and the earnest student is eager to gain engineering knowledge. It is easier to teach facts and methods than it is to inspire and stimulate thought; it is easier to learn facts and methods than it is to think.

The tendency of nearly all engineering teaching is to degenerate into filling the student's mind with knowledge to the neglect of training him in the power to think for himself. To be sure, one can not obtain much knowledge without some thought nor can one think without using and obtaining knowledge, but it is the purpose of the teacher as carried out in his methods which determines largely the amount of real thinking which the student does in obtaining his knowledge. Any teacher will grant that the student should think while he is acquiring knowledge, that he should know the meanings of the facts which he learns, that he should know the reasons for things; but when it comes to the actual work of teaching, these things are often forgotten. It is taken for granted that students think when they prepare for a recitation or listen to a lecture. Often this is true, but any experienced teacher knows that many of them are satisfied to know merely facts and formulas, while some are content without even these if they can only make the instructor believe that they know them. It is not surprising that this should be so, for much of the teaching is of just the character to discourage thought. The student will not be encouraged to find the reasons if the instructor is busied chiefly in plying the student with facts and methods and then finding out how many of them are remembered. Facts and formulas are necessary, but obtaining a knowledge of these should not be mistaken for obtaining an education. The instructor should use them not as important chiefly in themselves, but very largely as

only a means for drilling the student in the general principles of the subject. The student should be trained to perceive the relations between formulas and principles, although the fewer the formulas and the more the reasoning without them, the better educated will the student be. The teacher's task is to see that he does perceive the relations, does get ideas, and this task can not be accomplished by merely telling him to find the reasons for things and then assuming that the learning of the facts is evidence of the getting of the ideas. The true teacher continually contrives to stimulate real thought, and this he does by calling into exercise the reasoning faculties much more than the memory. The memory is a useful and valuable faculty, but often the teacher who is untrained in pedagogical methods will unintentionally devote to the exercise of this faculty attention altogether out of proportion to its importance.

An engineering education should give more than a knowledge of fundamental principles and their relations to engineering facts. It should give also a training in methodical ways of thinking, in methodical ways of doing work or arranging data and computations. A mere familiarity with good methods is not sufficient. There must be developed also an appreciation of the value of method and a habit of doing things methodically. The methodical habit of mind is the important result to be obtained rather than an extensive knowledge of engineering methods. The thoughtful teacher will concern himself chiefly with mind, using methods and information more as means for developing mind power than as so much useful knowledge to be imparted to the student, which he stores away in his memory ready for use when called for. The power to think, to solve new

problems, to devise new methods, and to work efficiently is the important and lasting benefit of an engineering education, and the main purpose in the teaching of any subject should be the development of this power in the student's mind.

What has gone before must not be construed to mean that knowledge of facts and of methods of drafting or design or field work is not an important part of the education which the engineering student receives. In these days of the demand for the so-called practical education, it is necessary that the engineering colleges should furnish courses which will give a considerable amount of engineering information and some skill in doing engineering work. It is expected that the future engineer shall be ~~shall be~~ able to earn a fair salary as soon as he is graduated, and the education must be planned to enable him to be useful to his employer. Much of the information which the student receives will be useful to him, but on the other hand much of it will never be called into use. Most of it is forgotten within a few years after graduation. Surely the teaching of so much knowledge which is so soon to be forgotten can not be justified chiefly by the fact that the student does not know what knowledge he will need and must therefore obtain a knowledge of many things so as to be prepared for the particular kind of work in which he may engage. The teaching has all served a purpose, if properly done, even though the knowledge is largely forgotten.

The development of mind and character which comes from an intelligent acquisition of knowledge and a diligent performance of daily tasks, is the lasting benefit of an education, and the main purpose of the teacher should be to bring about this development . Although much of the subject matter taught must be largely informa-

tional in order to meet the demand for what is called a practical education, it is possible to make all the instruction contribute towards the development of the student's best powers, if the purpose be kept ever in mind and if the methods of instruction be carefully chosen with a view to accomplishing that purpose. The student's mind will doubtless broaden and strengthen to some extent even under indifferent teaching, but the development which he thus attains against odds is much less that might be accomplished under an instructor who has a higher aim than mere instruction. Education and instruction must go hand in hand. The development of intellectual power and the acquisition of knowledge are not separate; each is necessary to the other, but the lasting and most valuable thing which the student receives is intellectual power, and this it is which every true teacher will strive to develop.

III. PEDAGOGICAL PRINCIPLES.

In various parts of this paper the principles of pedagogy are dealt with as occasion demands, but there are a few of these principles that require especial mention at this time. No attempt is made to discuss the subject in a technical manner, the object being to present a few ideas that will be of service to the inexperienced instructor, and not to give a logical treatment of the science of teaching.

The teacher needs often to remind himself that his principal field of work is the mind of the student, not the subject matter to be taught. He must know something of the laws of mind and conform his methods to those laws. Moreover, since different minds have different capacities and different limitations, he should endeavor to learn, as soon as possible and as much as possible, the individuality of each student in his class. To this end there should be free interchange of ideas between teacher and student both in and out of the class room. Frankness and candor should be encouraged. The desire to learn must not be smothered by the fear of showing ignorance. The student should be made to feel that the instructor is with him, not over or against him. He should be made to feel that he is being fairly treated and not taxed beyond his powers. Resentment and discouragement are feelings which operate strongly against the acquisition of knowledge in the class room as well as tend to prevent faithful study outside of it. Anything which prevents full sympathy and understanding between instructor and student is to be avoided.

Attention on the part of the student is absolutely

necessary in order for the instruction to be efficient. This fact is well known, but often not enough thought is put upon the means for insuring attention. There are two kinds of attention: one which is easy and natural, arising from interest and curiosity; another which the student forces upon himself from motives of self interest. The latter is often the only kind upon which the teacher depends. Most of us can remember instances in our own student days of the great difficulty of giving constant attention when the subject matter taught and the manner of the teacher were both uninteresting. A live teacher can usually make his subject interesting if he sets out to do so, especially in an engineering college, where there is a predisposition upon the part of the student to be interested.

An alert, brisk manner upon the part of the teacher helps in holding attention. An indolent teacher will have a dull class. It is not advisable to sit while conducting a class as a teacher can put much more life into the class work when standing. Open inattention is the sign of poor teaching, for a good teacher exacts at least the appearance of attention, and he usually succeeds in getting more than the appearance. Bringing the progress of the recitation or lecture to a stop for the obvious purpose of waiting for certain inattentive students to give heed is usually a sufficient rebuke. Another and a very effective plan is to ask unexpected questions in an ordinary tone of voice and then call upon the inattentive one to answer. With proper stress laid upon the necessity for attention, the student will be reluctant to be caught off his guard in this manner. Of course the question should not be repeated after the name is called. Open inattention must be checked at once, and this

can be accomplished only by the instructor himself constantly giving his attention to the class before him. It is not a good practice for the instructor to use any of his time and attention in recording grades on recitations while the class work is in progress. It sets a bad example in the matter of giving constant attention to the progress of the recitation, or it involves wasteful pauses for the recording of the grades. Such a plan, moreover, can hardly fail in creating an exaggerated notion of the importance of grades and of the quizzing function of the teacher. It is important, of course, to have some way of holding students to diligent study and of keeping some record of their accomplishment, but recording grades in the class room is not the right way. A teacher can not attend properly to guiding the class room work and keeping the class attentive at the same time he is judging recitations and recording grades. If inattention is general and persistent in the class, the instructor must look for the cause in his own methods and must modify them to meet the conditions. Good order also in the class room is just as necessary in the college as in the graded school, for disorder and attention can not exist at the same time. No teacher can afford to allow disorder to get a start.

Although a drawling and listless manner is to be avoided, there is danger in too much briskness and speed. There must be time enough allowed for the ideas presented to be taken in; if this is not done, despair and inattention will result. Too much talking by the instructor is also to be avoided; the man of few words is heeded more than he who talks overmuch.

When a student recites, he should be required to speak distinctly enough for all to hear, and the others should be required

to hold themselves ready to criticize or discuss the recitation made. For arousing interest and holding attention, an excellent plan to follow when the recitation is in the nature of demonstration or explanation is to require the one reciting to talk directly to the class, not to the instructor. He should occasionally be required to explain further or to answer questions upon points raised by the others, without the instructor taking any part in the discussion. Constant observation of the success of these and of various other devices for keeping the attention of the whole class during the recitation will greatly increase the teacher's efficiency and will add much to his own interest and satisfaction in his work.

In all good teaching repetition is much used for fixing in the mind the knowledge which has already been gained. No student can be expected to remember all that is taught in each subject, but a few fundamental principles with some of their applications, he should be expected to know permanently. Reiteration is the secret of fixing firmly those things which it is considered essential for the student to know. It matters not how clearly or how impressively important principles or methods are brought out in the class room the first time, they have little chance of becoming a permanent part of the student's knowledge until frequent repetition of the ideas has made them permanent. This fact is so patent that it seems hardly worth stating, yet it is not fully appreciated either by instructors or students.

The order of treatment of a subject should be logical, and the connection between the lessons should be brought out by the teacher. In imparting new knowledge use should be made of that which has already been acquired. In this way new ideas are more

readily grasped than when new matter is treated without any connection being shown between that which is already known and that which is to be learned. By constantly using the old in developing the new, the advantages of repetition are also obtained. Moreover, the student's mind should be prepared for the ready grasp of new knowledge by having the purpose or aim pointed out at the beginning. He should not be left to wonder what it all means and what it is good for, otherwise his attention will wander and his interest lag. The development of the lesson then should be orderly and logical, lest the mental energies be dissipated in trying to grasp connections or lest no connections be perceived. The manner of presentation of new knowledge should be carefully planned and not left to chance development in the class room. Let the student see that all which he has learned is part of a logical whole and that the new matter is also a part of the same whole and is worth learning, then he will not only take a greater interest in the new knowledge but will also gain a more comprehensive grasp of the subject than if the different lessons are allowed to seem separate and disconnected.

Knowledge gained by hard study on the part of the student is retained much better than that which is told to him in the lecture or class room. The reason is found in the greater amount of time and attention given to obtaining the ideas. A greater mental effort is often required to follow the reasoning in the text-book than would be necessary in following the same line of reasoning when presented orally by the instructor, since more steps are left in the former case for the student to supply. The greater the effort put forth in obtaining knowledge the more prized and the more thorough the knowledge will be, provided the effort is not misdi-

rected. The mere understanding of a proposition is not equivalent to knowing it. The idea must be stamped upon the mind either by repetition or by close and continued attention such as is required in home study. Not only is knowledge better retained when gained by hard study but also the powers of the mind are more vigorously exercised and correspondingly developed. Only by mental exercise is mental strength acquired. There is no easy road to knowledge. The teacher who attempts to make the road easy by telling and explaining that which the student can acquire with greater effort and attention in his study will be popular but inefficient.

Often the more or less vague concept which the student obtains from reading or listening to a spoken truth is mistaken for a knowledge of that truth. The sure test of knowledge is the putting of the ideas into spoken or written statements. The inability to do this is good evidence that the supposed knowledge was not really possessed. Moreover, knowledge which is not fully comprehended at first, becomes more definite and more firmly fixed in the process of stating it, from the necessity of choosing words, which have definite meanings, to express the ideas. As a rule, written statements are better than spoken ones for this purpose. The instructor should not only use this test and pedagogical aid in the class room, but should also teach the student to apply it himself in the preparation of his lessons.

Important principles or general truths need repeated applications to particular cases in order that they may be more thoroughly comprehended and more enduringly fixed in the mind. The solution of many problems is very necessary in acquiring a good working knowledge of engineering subjects. Care must be used, however,

to see that the student perceives in the problems the important truths of which the problems are merely applications, else the value of the problems is largely lost.

To conclude this topic a few rules are given which the teacher should follow if he would be skillful in the art of questioning.

1. Ask many questions. The right kind of a question arouses thought, since the natural thing to do when a question is put is to supply the answer. One of the best ways to give the student knowledge is to require him to arrive at a desired conclusion by answering one or more questions leading up to that conclusion.

2. State the question, pause, look around the class, and then call the name of the one who is to answer. Each student is then aware that he is as likely to be called upon as any other and is busy planning his answer. If the name is called first, the rest of the class are likely to pay little attention to the question and less to the answer. Order and the appearance of attention may be present, but real attention will probably be lacking, for real attention means mental activity. The best teacher will contrive to excite mental activity by asking the questions in the manner above described. The practice of calling on students in turn, alphabetically or according to position, is rarely used by a good teacher.

3. Call on the student who is apparently the least attentive. The question having been stated before the name is called, it will be impossible for him to answer, if he has not been attentive, other than to say he does not know or did not get the question.

4. Do not repeat a question. If a student asks for

a repetition of the question, it is evident that he was not paying attention. All the value of the method of questioning already described is lost if a second statement of the question is given. The instructor, of course, must use care in his wording and enunciation so that the fault shall not be in himself. If he has good reason to believe that the fault is his own, he may properly repeat the question in a different manner.

5. Do not ask a question which can be answered by "yes" or "no". Little mental effort is necessary to make one of these two answers. The question should be so stated as to require the making and statement of a judgment on the part of the student.

6. Ask the question in good English and require the answers to be clear and complete sentences. Clear thinking requires the use of clear, concise wording. If looseness of language is permitted in answering questions, looseness in ideas will result. It is not the best teaching to allow the student to answer by giving only a word or a part of a predicated statement, the remainder being implied in the teacher's question. In formal recitations require full sentences for answers to questions.

7. Make it a practice to call upon each student for a recitation at least once every day. Each one should expect to be called upon every day for any part of the lesson. It is better, of course, to have each student recite several times each day rather than only once.

IV. METHODS OF INSTRUCTION.

Several more or less distinct methods are in use in teaching engineering subjects, as follows: 1. By lecture. 2. By recitations. 3. By laboratory practice. 4. By individual instruction. 5. By design. 6. By seminar. It is not intended to discuss in this paper the last two, although both have their peculiar advantages and should not be omitted in a full course in engineering. The attention will therefore be directed to the other four methods. None of these is ordinarily used entirely alone in any subject, but usually one of them will predominate over the others. Some subjects lend themselves peculiarly to the lecture method, while others can hardly be taught well in any other way than by class recitations. The best results, however, are usually obtained by using a judicious combination of two or more methods.

1. THE LECTURE METHOD.

The lecture method used alone is perhaps the simplest and most economical to the college and is also the least efficient of them all. There is some difference of opinion among educators as to the extent to which the lecture method should be used. However, the belief is pretty general that it is not well to rely much upon this method in teaching undergraduate engineering students. The latter are not usually able to take down a good set of notes, either during or after the lecture. The purpose of the lecturer should be to give ideas to his hearers, and close attention is necessary upon the part of the student if he is to get ideas; but if the attention is given to taking notes it is impossible to get the ideas well. Without the notes, though the hearer may grasp the

ideas for the moment, he will not be able to retain them long or to use them. The difficulty here can be largely obviated by giving the student a copy of good notes or an outline for each lecture, thus enabling him to give his full attention to the lecturer. The student must then supplement the lecture by reading the reference books or by studying a text-book. If the student could be depended upon to listen attentively, to get correctly the ideas presented, and to read with discrimination and understanding, the lecture method might be considered efficient. Every experienced teacher knows that the average undergraduate can not be depended upon to do all of these things. He will often obtain erroneous ideas from the most carefully prepared lectures and from the best of text-books. Some means for finding out and correcting these erroneous ideas must then be used if the lecture method is to be made effective. One or two oral quizzes for each two or three lectures will furnish the opportunity for detecting the mistaken ideas and setting the student right.

Other and more important weaknesses in the lecture method can not be so easily remedied. Although the lecture is useful in presenting knowledge to the student in such a way that he will understand it and be interested, it is not so useful in helping him to make that knowledge his own. Often he thinks he knows a thing because he can see that it is true when it is explained to him, and yet he may not really possess the knowledge at all. Something more than mere intellectual assent is necessary. The student must be able to formulate the ideas in words of his own choosing before he can be said to know them. Sometimes he will say that he knows but can not state the idea. Possibly he is right, but if so he surely needs the training which comes from formulating definite statements.

The only way for the student to develop the ability to state his ideas is to keep stating them, so the quiz used in conjunction with the lecture should be used as a means of training for the student as well as a means of showing the instructor how much or how little the student knows. The quiz then becomes practically the same as the ordinary recitation, but coming less frequently, it does not give as much training of the kind here discussed as seems desirable.

The lecture method is also wasteful of time. It usually takes much longer to present a given amount of information by lecture than is required for reading the same amount of information in a good text-book. In the days when text-books were few and poorly written there was more reason than now exists for giving much of the instruction by lecture. Sometimes the ideas can be more readily grasped when presented and illustrated in a lecture, but when this is not the case, it is wasting the student's time to require him to spend an hour listening to that which he can get just as well in half an hour by reading.

With all its limitations the lecture has an important place in educational work. In the teaching of large classes in elementary science it is very generally used, in conjunction with quiz and laboratory work. If the lecture is ably given by one who is an authority, the subject can be given greater interest than if the text-book is used alone. The lecture should be used, however, to supplement the text-book rather than to displace it. The average student needs a text-book, no matter what may be the method of instruction.

The lecture can be used occasionally with profit in teaching almost any subject with which other methods are ordinarily

used, for the purpose of giving variety and interest to the work. An occasional rest from recitation is welcome to the student and is likely to be beneficial. Another use for the occasional lecture is the supplying of matter which may be considered important by the instructor, but which may be omitted or inadequately treated in the text-book used. Experience will show, however, that unless much care is used in thus presenting knowledge, it will not be well grasped. When the student is required to show his knowledge of the matter thus presented, it is likely to be recognizable from its similarity to the original, but will very often be worthless on account of its incorrectness.

2. THE RECITATION METHOD.

Advantages of the Recitation Method.

The recitation method is the one most used in teaching engineering subjects and it is without doubt usually the best. The lecture and the laboratory may also be needed, but the recitation should receive the most attention in most subjects. The necessity for preparing to recite upon any part of each lesson is the most efficient incentive for diligent study. As long as conditions are not ideal, as long as students need outside pressure to hold them to their tasks, so long will the recitation method be the most efficient.

One of the chief merits of the recitation lies in the benefit which the student derives from the association with his fellows. In the class room erroneous ideas are detected and replaced by correct ones. The whole class learns from the mistakes made in the recitations as well as from the correct statements. Different students will see different sides of a problem, and together they will arrive at a fuller comprehension of the subject than they would

be likely to obtain from a lecture or a text-book. Questions asked by some members of the class bring up difficulties not thought of by others. Difference of opinion brings out discussion and argument which are useful in stimulating independent thought.

More important perhaps than any other benefit is that which comes from the definite statement, by the student, of the knowledge which he has obtained from his study of the lesson. Only when he can state his knowledge clearly and make applications of the principles learned can the student truthfully say that he really knows. The student learns that mere reading is rarely sufficient to give him knowledge which he can divulge to others or apply to the solution of particular problems. He thus learns the necessity of studying that which he wishes to know. The study of the lesson as usually made is not sufficient in itself, however; there needs the recitation to aid in bringing the idea clearly into the mind of the student and fixing it in the memory. Of course the mere memorizing and repeating of statements or formulas given in the text-book are not worthy of the name of study and recitation, and no competent teacher will permit mere memorizing to pass for studying.

The recitation also offers better than any other method the opportunity for giving thorough drill in the fundamental principles by means of frequent repetition and application of those principles. The frequent reviewing of the most important parts of a subject is found to be most effective in fixing firmly those things which it is considered essential that the student should know and be able to apply.

Functions of the Teacher in the Recitation Method.

The work of a teacher in handling a class may logically

be divided into three parts; namely, making the assignment, the hearing of recitations, and the giving of instruction. Each part is important and should be carefully planned in accordance with the principles of correct teaching.

The assignment of work for the student to perform is often looked upon as a routine matter of minor importance. The fact is that the teacher's success depends considerably upon the careful performance of this part of his work. The too common practice of waiting till the time for dismissing the class and then hurriedly assigning a number of pages for the next lesson is to be deplored. Often this is done without the instructor having looked carefully over the advance lesson. Frequently he will find that he has assigned paragraphs which the student might better not study, and will wish that they had been omitted. It is an injustice to the student to have him study the whole assignment and then to tell him that parts of it are unimportant or incorrect. The instructor should prepare the assignment carefully in advance, and in stating it he may well indicate what are the important parts of the lesson, if the student can not reasonably be expected to discriminate. A brief outline of the work to be covered, showing its purpose and its relation to the subject as a whole, may be practicable and is useful in giving greater breadth of view. In order to accomplish good results along this line it is best to make the assignment at the beginning of the recitation period when close attention can be obtained.

In considering the second division of the teacher's duties, viz. the hearing of recitations, several distinct functions of the recitation should be kept in view. Among these are, to show

to the instructor what the student has learned, to show how diligently he has performed his tasks, to bring to light erroneous ideas in order that they may be corrected, and to help fix ideas by repeated statement in the class room. These uses are important and are usually appreciated at their full value. Another and less recognized use for the recitation is found in the opportunity it holds for giving valuable training. Some training will be furnished even though the instructor has in mind only the purpose to find out how much or how little has been learned, but it is not to be compared to that which might be given if he has the higher purpose to make every exercise contribute to the stimulation of thought and the development of the mental powers. The student needs to be trained to see relations and to state conclusions for himself. His recitation then should often take the form of a series of statements or conclusions given in answer to questions skillfully planned to lead his mind by logical steps from that which is already known to that which is new. By this means his mind is trained in correct processes of thinking.

By the giving of instruction, which was mentioned as the third division of the teacher's work, is meant that part of his duties which consists in telling or explaining things to the student as distinguished from having the student do the telling. It includes not only the more formal instruction given by means of a lecture or continuous talk, but also the occasional bits of instruction such as the answering of questions or the giving of suggestions for solving a problem. In the performance of this part of his work, the teacher must exercise much care if he is to be successful in developing the minds and characters of his students. As one prominent teacher has

said, the instructor who instructs too much soon loses his efficiency. His duty is first to interest and stimulate the minds of those in his charge so that they will not shirk hard work, and then to teach them how to work. Clearly this duty can not be performed by doing the student's thinking for him, by answering all his questions, and by helping him over all his difficulties. The teacher's help should be given only when the student is not able with reasonable effort to do for himself. The easier way for the teacher is to explain the difficult parts of the lesson rather than to require the student to master them, to answer all his questions and give help indiscriminately rather than to encourage or require him to rely upon his own efforts. This is the way which the sympathetic and easy-going instructor will take. One who is exacting and unsympathetic tends to the opposite extreme of giving no individual help. He says virtually: "Here is knowledge in lectures and text-books. If you can not do the work without help, you must fall behind. It is not my business to help you." Both extremes are to be avoided There are times when help should not be refused, and times when the student should be required to depend upon his own resources. How to take the middle ground, to be exacting when that is best, and to give help when help is really needed, is one of the teacher's hardest problems.

No kind of help which the instructor can give is more valuable or more neglected than teaching him how to study. Many boys have never been trained in proper methods of study and consequently waste much of the time they spend in preparing their lessons. It often happens that a large part of the class fails to get any reasonable grasp of a lesson which the instructor knows ought to be

well within the ability of the average student to get in the time allowed. Reports are common of three or four hours spent in the preparation of a lesson that should not require more than half that time. Such reports are so common that the only reasonable conclusion in many cases is that the fault lies in ignorance of how to study. Nothing else can be expected when we remember the absolute lack of any definite provision for training in matters of this kind. Why should the student be expected to know how to study well without any real instruction in the best ways to do it? He may in time learn something of good methods of studying by observation and experience, but how much better off he would be if his instructors would give him the benefit of their broader experience! What greater service can the teacher render his students than to teach them how to work? It is not sufficient to tell them to concentrate their minds and study hard. What they need in many cases is to be shown how it ought to be done. A definite attempt to give some detailed instruction of this kind at the very beginning of the term's work will be of great benefit to many students.

Different kinds of lessons need different kinds of treatment. Suppose that the lesson is chiefly informational, requiring the reading of several pages and the remembering of a good many facts. Let the student be taught to read the lesson carefully once, then again, this time marking the important and central passages, and lastly to set down in writing in his own words as many as possible of those things which he wishes to remember. The last step is very important, for nothing serves so well to reveal indefiniteness of ideas and to fix facts in the mind as expressing them in written words. The value and the method of making out a con-

densed outline should also be taught. If the lesson is one containing analytical treatment of general problems, the student should be taught first to understand clearly the statement of the problem, then to picture the conditions as well as possible by means of a carefully drawn sketch. The problem will usually involve applications of the principles of geometry or trigonometry, and the sketch should be accurately drawn in order to make it possible to show these applications. Usually there will be such a sketch in the text-book, but the student should always draw one for himself. Then he should follow the treatment of the problem as given in the text-book, writing it down only as fast as he perceives the correctness of each step. When this is done he should review the problem with a view to picking out the main points and fixing them in his mind so that he will have an outline by which to guide himself in reproducing the solution. He should not be content then until he has tested his knowledge by going over the solution without the aid of the book. It is very important at this point to take up all three parts of the work, first, a clear statement of the problem, second, the drawing of an accurate sketch with the necessary statements to explain it, and last the solution itself. With the first two parts well done, a mere outline of the several steps to be taken in their logical order may be all that is necessary to master the problem. Such a method of study once learned can not fail to be of immense benefit to the student. He learns to put his attention upon the relations of the various elements of the problem. Not equations and formulas, but relations are what he looks for and learns. The equations can then easily be supplied for they are nothing but the statement of relations. Several problems of this kind now become separate and intelligible parts

of the lesson instead of a jumbled mass in which the student uses the statement of the problem merely as his cue for reproducing a memorized set of equations inaccurately illustrated by a sketch drawn something like the one in the book but very often incorrect. The latter condition of mental darkness is the state in which many students are often found. To prove that this is true, it is only necessary to give a class an unusual test in a lesson of this kind by requiring them to write correct statements of all the problems in the lesson, with the proper figures to be used in solving them. In one test of this kind, not half the class were able to state correctly as many as two of the four simple problems in railroad curves which comprised the whole lesson. The unusual test served to show that many students fail to get any clear idea of what they are trying to do in this kind of work.

A few more points, stated in the form of rules, with relevant remarks, for the sake of brevity, will serve to show sufficiently the kind of things which the student needs to learn. A good general rule is, always study with the pencil in the hand. Draw neat and accurate sketches whenever it is possible to picture the conditions in this way. Such sketches are an invaluable aid to the engineering student, while careless and inaccurate sketches are usually worthless and are often positively misleading. Sketches need not be to scale to be accurate in the sense here used, although in some kinds of problems sketches drawn nearly to scale are very useful. Use a good pencil and good paper, and keep the written work neat and well arranged. Neat and systematic arrangement of written work reacts upon the mental processes, tending to make them orderly and correct, while untidy, jumbled work surely tends toward

confusion and mistakes. Without the aid of the text, set down in writing the facts and principles learned, as a test of the memory and understanding.

Enough has been stated to show what can be done in the way of teaching students how to study. The actual preparation of a lesson or the solution of a problem with the class may sometimes be the best means for getting correct habits of study started. Our system of education ought to make definite provision for giving training of this kind, but so long as such provision is not made, nothing of the instructor's work can be of greater importance than the teaching of correct methods of study.

Methods of Conducting Class Work.

Various devices or methods for conducting a class are in use. Some teachers prefer one method and others another, but the best teachers do not confine themselves to the use of only one or two. Interest is increased by variety in the method of carrying on the class work. A method which is good for one day's work may not be applicable to the next. An instructor should be familiar with a number of class room methods in order that he may use the one which will be most effective in each case. A brief description of some of the best methods used in teaching engineering subjects is given below.

1. Reciting in Place. In this method each student recites in his place as called upon by the instructor, while the rest of the class listen. For some purposes no other method seems to be as suitable as this one. It is useful in getting definitions of terms properly emphasized, in detecting and correcting mistaken ideas before much time and effort have been lost on account of them,

and in the clearing up of hazy ideas by requiring the student to express them in clear and direct statements. It is of most benefit to the one who recites, but it does much also for the others of the class as long as their minds follow the speaker to judge of the correctness of his statements. The chief difficulty here is to get all the class to attend upon the words of the one who recites. It is very difficult to force attention where there is little interest, and interest can not usually be maintained very long by this method. Some other plan should be adopted when practicable just as soon as it is found impossible to hold the attention of all, for it is a waste of valuable time to conduct a recitation for the benefit of one student only, if there is some good way to keep all the class busy thinking and working.

2. One Student at the Blackboard. This plan is somewhat similar to the one given above but is different in that it is used for a different kind of subject matter. It is used to advantage when sketches are necessary as in the demonstration of a proposition or the description of a method. The others in the class should be encouraged to criticize the recitation as to correctness and completeness. Excellent training for the one reciting can be given by having the others put questions to him and requiring him to repeat and elaborate until his statements or methods are made clear. The student should be taught to give his demonstrations and descriptions directly to the class, and not to the instructor; to assume that his hearers are not already familiar with the particular topic upon which he is reciting. If he can be led to take this attitude his statements and explanations will be made much more clear and complete than if he takes the usual position that his purpose is to

show the instructor that he has studied and understood the lesson. Requiring him to answer the questions and remove the doubts of his fellow students is one good way to help him to take the desired point of view. The same necessity for keeping the attention of the whole class exists here as in the first method.

3. Working in Unison at the Blackboard. All the members of the class work on the same problem, the data being given orally while the class is at the blackboard. This method is used when it is desired to give a number of short problems to be solved during the recitation hour. It is one of the most effective means for giving a working knowledge of the subject in hand. Definitions and theorems and descriptions are necessary, but there should be a large number of problems also, in order to make the student's knowledge of principles practical and permanent. The only practicable way to give a large number of problems and to be sure that they are solved is the method here discussed. The problems should be short and simple, requiring perhaps a minute or two, else the quick students will have finished and be standing idle before the slow ones get well started. It will not usually do, however, to wait for the slowest one to finish. When most of the class have finished, work may be stopped while one student explains the solution for the benefit of those who did not get it, and then a similar problem may be given. This plan serves well to show who are the dull and delinquent students but does not deprive them of all the benefits of the problem work, provided they have made some preparation and have given attention in the class room.

4. Individual Work at the Blackboard. The method here in mind is similar to the one just described but differs from it in

that each student has a separate assignment. The latter may be the solution of a problem requiring a numerical result or it may consist of the analytical treatment of some general problem. If the class is large it may not be objectionable to give two or three students in different parts of the room the same assignment. The usual way is to make each separate assignment orally, but one which is called the card method is much better. In this method a standard filing card containing the assignment for blackboard work is handed to each student.. Work begins at once with a minimum of confusion and delay and a consequent saving of time.. The common method of stating aloud a half dozen or more different assignments either before or after the class is in place at the blackboard will usually take five or ten minutes. This time, which is practically wasted, is a considerable percentage of the recitation hour, and it can easily be saved to the class if the instructor will take the time to prepare cards with the statements and data on them for the problems to be solved.. The cards can be filed away and used again in a review or in teaching succeeding classes. Although a little more work for the instructor is involved in the first year or two when the cards are prepared, there is a saving of work in all the following years. A list of solutions for the problems is of course very useful to the instructor in aiding him to follow closely the work of the students. A very good plan is to use another set of cards of a different color, each one containing the solution for a corresponding problem on a student's card..

Besides the saving of time in making assignments which the card method makes possible, there is the added advantage that fewer mistakes in copying the data will occur.. The instructor is

also less likely to make mistakes in giving the data when the assignments are written and checked deliberately. The method is especially useful when, on account of lack of blackboard space, part of the class are occupied in making oral recitations at their seats while the rest are sent to the blackboard. In making the assignments, it is well to mix up the cards in the presence of the class and then give them out without choosing; otherwise there will usually be a tendency to assign the difficult work to the bright students and to leave the easier problems for those who are dull. Each one should be taught to expect the hard problems just as much as the easy ones, for if a student finds that he is usually called upon for the easier problems he will not be likely to study the difficult parts of the lessons assigned.

When numerical problems are assigned for study in the preparation of the lesson, it is better in general to give different problems for class room work, although the new ones may well be similar to those already studied. If new problems are not used, some of the brighter men will find little interest in repeating what they have already done, while others who may have had to obtain assistance in their preparation work will not get sufficient training in doing their own thinking. If the card method is used the text-book problems need not be relied on for the class room work, and the disadvantages of devising problems off hand are also obviated. A carefully built up card collection furnishes more satisfactory problems than can be obtained in any other way.

5. Problem Work Outside the Class Room. Some problem work is assigned in most engineering subjects for study in the preparation of lessons, but it is intended to discuss here only the more

or less systematic assignment of problems to be handed in at stated times. Although this is not one of the methods of handling a class during the recitation hour, it is one of the devices used in connection with the recitation method and is well worth consideration. The card method, which has already been described, is here also a most valuable aid in the systematic development of the problem work.

The usual way of giving out a problem, by placing it on the blackboard for the students to copy, is open to criticism. Several minutes of valuable time from the recitation hour is required for copying the data; the student is likely to make mistakes in copying; the instructor may make a mistake in stating the problem or omit some necessary data; and the student's attention is likely to be given to this new problem during the recitation hour when it ought to be on the work in hand. All of these difficulties could be removed by giving to each student at the end of the hour a printed or mimeograph copy of the problem.

The main purpose in all problem work should be to deepen the student's knowledge and give him desired training. The problems should be carefully designed, when practicable, to make a connected whole, each problem depending upon or including something of what has gone before. They should be planned to bring in applications of the principles studied, in order to give those principles definite meaning to the student. It is a mistake to let it be the main purpose to develop proficiency in solving certain kinds of problems. It is not the ability to solve any particular kind of problem but the knowledge of the principles involved that is chiefly valuable. The training received in systematic and accurate habits of work is also of great value. The proper functions of problem work

should always be kept in mind in order that the greatest amount of good may come from such work.

One of the most difficult things to teach a student is the necessity for cultivating the habit of accuracy. The unreliability of the average student's computations is notorious. The idea is altogether too prevalent that if the method used is right, the correctness of the result is not very important. The systematic problem work here discussed affords a good opportunity for cultivating the habit of accuracy in computations. One method for emphasizing the importance of accuracy is to give it much weight in the grading of the problems. Some go so far as to give no credit for a solution which gives a wrong result, even though the method is correct, and to give full credit when the right result is obtained. This position seems to be extreme and unreasonable. Certain it is that such marking is not at all practicable in some subjects, when the problems are somewhat complex or consist of a number of similar parts. The instructor who requires new problems to be solved in place of those which have wrong results will be continually busy correcting papers. Some means, however, must be used for putting a premium upon accuracy.

The instructor should teach not only the importance of the habit of accuracy but also the methods for cultivating the habit. He should teach in the class room the value of frequent checking of results and should continually require checking to be done in order to develop as much as possible the habit of checking. Let him show the student the methods which he himself uses to find and eliminate mistakes. Teach him how to estimate or calculate roughly the result, when practicable, in order to avoid gross blunders. Teach him to

inspect his work as he proceeds, to keep his eyes open and to use his common sense, so that he shall not proceed further after making such mistakes as getting for the product of a number and a cosine a result greater than the number itself. Teach him also to check his work by independent methods of calculation. In short, do not merely tell the student to be accurate, but show him how to be accurate, and train him gradually into correct habits by continual hammering away along this line. And while teaching accuracy, let the teacher of engineering subjects not fail to teach consistent accuracy as well. This is a subject which has been sadly neglected in the past; neglected to such an extent that many engineers make themselves a laughing stock in the eyes of scientific men on account of their absurd and inconsistent refinements in measurements and calculations. It is time that teachers of mathematics and engineering should acquaint themselves more fully with the subject of consistent accuracy and then teach as much of it to their students as the latter are able to comprehend.

In marking the problems, various points such as accuracy, method, clearness, arrangement, neatness, etc., are to be considered, depending upon the subject and the way in which it is taught. Some would mark with reference to the first two points only, but in some subjects, such as surveying, other things are also of much importance. It is very difficult, if not impossible, to give any definite standard for grading problems which are not entirely correct or satisfactory. Probably the most reasonable and most definite position to take is that the marking should be made with reference to the grade necessary for passing. If 70 is the passing grade, indicating the minimum of a fair working knowledge of the

subject, then those papers which, if representative of all the student's work, would barely entitle him to pass should be marked 70, and the others above or below 70 according to their relative worth. Each instructor will have his own ideas as to what constitutes a fair knowledge of the subject, but if he mixes with his fellow instructors, has good common sense, and remembers that young students can not master all that is put before them in the subject, he will very likely conform closely to the standards of the institution in which he is employed. Whatever may be the basis of grading, the papers, with criticisms and mistakes indicated, should be promptly returned to the student in order that he may know wherein he has fallen short. It is probably better to return the papers without definite grades marked upon them, lest the student direct his attention more to the grade received than to the mistakes and criticisms which chiefly warrant the return of the papers. When too much work for the instructor is not involved, it is well to require the problems to be handed in again with the corrections made. At any rate, some method should be used to get the student to obtain some real help from having the problem criticized. One way which is used is to keep the problems on file in the office and require the student to come and discuss his solutions with the instructor. A problem which is very badly solved should be returned for a new solution or a new problem should be given in its place. The card method is valuable here again if a large number of problems is on file. It is a good rule to follow not to give out a new problem until it has been solved by the instructor, lest unforeseen difficulties in the solution cause the student confusion and delay.

One of the instructor's chief difficulties in teaching

by problems is to secure individual and independent work. Many teachers make it a practice to give out the same problem to the whole class, requiring that each student shall present a solution which is his own. Of course, there is then no certain way of assuring individual work. Although there are some advantages in students discussing with each other the method for solving a problem, the disadvantages will outweigh them in most cases, so that it is better, on the whole, to require that each student shall depend wholly upon his own resources in such work. There will usually be all degrees of violation of such a requirement. Some students will work together, dividing the labor, others will depend upon receiving help from their brighter classmates, and some lazy or dilatory ones will copy whole solutions from the papers of their industrious friends. An obvious way to prevent the last offense and reduce the others to a minimum consists in giving a separate problem to each student. This plan involves a much greater amount of work for the instructor, which makes it impracticable if the class is large. It is doubtful whether the greatly increased work is worth while for preventing the small amount of fraud and undesirable collaboration in solving the problems, which can not otherwise be prevented. A good teacher should be able to impress upon his students the importance and necessity for independent work to such a degree that there will be little loss of efficiency from the fact that all the members of the class have the same problem. They should be taught that only by doing their thinking for themselves can they hope to train themselves to become good engineers. Those who at first refuse to heed counsel and instructions will find in the written quizzes that only by solving their problems

themselves will they be able to handle the quiz work. The student that depends on copying the whole problem will soon be detected by the alert instructor, who will then have a problem of his own, calling for the exercise of all his wisdom and judgment. The wise teacher will usually be able to avoid the necessity of dealing with such cases by giving frequent short quizzes which will require a knowledge of the solutions handed in, as well as by cultivating such a moral standard that copying will rarely be done. After all, it is hardly wise to attempt to force honesty and individual effort by resorting to all possible measures to prevent dishonesty. Something may well be left to the honesty and good sense of students until those qualities are found lacking.

The tendency of many students to hand in problems late is one which causes much vexation and inconvenience for the instructor. The instructor's convenience, however, is not the most important consideration in this matter. Promptness is a virtue which the engineer ought to possess, and the student of engineering must not be allowed to disregard it in his school work. Moreover, it is not practicable to return as soon as they ought to be returned solutions which have been criticized and marked by the instructor, if some who have the same problem have not yet submitted their solutions. The dilatory student has not only the greater reason or temptation to get help from another's work but also has a better opportunity to do so after some of the problems have been returned. A discussion of the problem and its solution in the class must also be delayed on account of the lateness of some students. Lateness should be strongly discouraged. The importance of promptness as a virtue should be properly emphasized, but that will not be enough.

Only partial credit should be allowed for late problems and there ought to be a short limit of time beyond which a problem is not accepted for credit. If this limit is exceeded, the dilatory student should be given a new problem to solve in order to get the necessary credit, and, of course, full credit should not be given for the substituted problem.

In enforcing such a plan for discounting lateness, the plan itself and the reasons for adopting it should be made very clear at the beginning of the term. The class should be brought to see that a course of this kind is best for the individual student and also for the general good. The sympathy and cooperation of the students may well be enlisted by asking them to pass judgment upon the reasonableness of the proposed plan. The plan should be reasonable in fact or it will not receive approval, but if it is reasonable the approval will not be withheld. The student must be made to feel that he is being given a square deal. Sickness or other good cause for lateness in handing in problems must not be ignored. Although some definite plan of general procedure in dealing with late problems may be desirable it must be recognized that exceptions ought to be made in some cases. In short, the instructor, while emphasizing promptness and discouraging its opposite, must be just and reasonable in all his dealings if he would secure that sympathy and respect of his students which is necessary to make his teaching most effectual.

6. Instructor at the Blackboard. When it is necessary for the teacher to instruct the class in order to correct wrong ideas or to explain some obscure point, it is very desirable that he should picture his ideas at the blackboard whenever practicable.

Most students can grasp an idea much more quickly and clearly with the aid of a good blackboard sketch than without it, and in some subjects such sketches are necessary. When the instructor talks at the blackboard to his students, he not only instructs them in the immediate subject of his discussion but he also teaches them by example how to make their own recitations. He should be skillful in illustrating by sketches, and he should make his explanations clear and logical. He may well call attention to the order and method of treatment in order to teach how to present knowledge correctly.

Another occasion is found for the use of this method when the instructor wishes to enlist the mental activities of the whole class in solving a problem quickly. The solution is made or indicated on the blackboard as fast as it is worked out by the class. The instructor calls upon individual students to give the various steps in the solution, in order to hold attention, prevent confusion, and to test the knowledge of those called upon. If quick, short questions are used and quick answers required, this method serves to arouse alertness and to save time by making it possible to cover a given amount of work more quickly than a single student could do it. When the instructor is doing most of the talking himself it is well to ask an occasional unexpected question in order to insure close attention.

7. The Surprise Quiz. One of the constant difficulties in the way of the instructor is the neglect of study on the part of the student. After all is said and done to create an interest in the subject and a desire to work, there will be some who are likely often to neglect the preparation of the lessons, thinking they can get in class what they fail to study at home. These students can

and will study if they are, in a sense, compelled to do so. This is a condition which the instructor has to meet, and he should adopt the best methods for requiring study. There is probably no more effective device for putting a premium on faithful preparation for every recitation than the occasional short written quiz on some point in the lesson for the day. To be effective the quiz must of course be wholly unannounced and be given at irregular intervals, for though it need not be given every day it must at least be expected every day. It should usually be short and easy, covering some simple point in the day's lesson, so that any reasonable preparation will enable the student to do the required work in ten minutes. On the other hand, the quiz should be of such a nature that a failure to prepare the lesson will make it impossible to do anything at all with it. By laying sufficient emphasis upon the importance of the showing made, this method when skillfully used will often bring even the most careless students to the habit of regularly preparing for their recitations. Experience shows that the best preparation is usually made in those studies in which the most pressure is brought to bear, and the short surprise quiz is found to be an excellent means for putting on the pressure.

8. The Announced Quiz. Some teachers use almost altogether the announced quiz instead of the surprise quiz. It is surely more effective in securing good papers, for the student is usually made to feel that much depends upon the quality of the work done, and he consequently makes use of the opportunity given to prepare for the quiz. For the purpose of requiring an occasional review during the term this plan is probably the best that can be used. Many teachers, however, believe that the student should be held re-

sponsible all the time for a reasonable knowledge of all the work covered and that he should hold himself ready to write an acceptable paper without being given any special opportunity for review. Surprise quizzes help to keep up the faithful daily preparation of lessons, and announced quizzes serve to secure a thorough review, which is occasionally desirable. Both kinds should probably be used, although it is well to have very few announced quizzes. Objections to the latter are found in that students usually neglect their lessons in other subjects when studying for a quiz, and also in the fact that they are sometimes over-burdened with such work when two or three of their instructors happen to announce quizzes for the same day.

The principal methods for conducting a recitation class have now been considered. Besides these more or less distinct methods there are many combinations used, depending upon the subject matter of the lesson and the purpose in view. No one method will be found sufficient. Each has its proper place, and it is the business of the instructor to choose carefully the best means for accomplishing his purpose. Just as he expects his students to know the relative advantages and disadvantages of various methods in computing or designing, he should know the same concerning the various class room methods in his business of teaching. Recitations should not be conducted upon consideration of mere convenience nor in a haphazard manner upon no consideration at all. Careful thought must be devoted to the details of the class room work, in order that the systematic and efficient methods which are necessary for the accomplishment of the best results, may be discovered and used.

3. THE LABORATORY METHOD.

The great and rapid development of laboratory facilities

for the teaching of applied science is an indication of the value which this method is believed to possess. Without doubt, laboratory practice is a most useful aid, and it is properly considered almost indispensable in the teaching of many engineering subjects. Nevertheless, much of the laboratory work which is done falls far short of accomplishing what it should. Some experienced teachers believe that this kind of instruction as frequently given is the least efficient of all. No attempt will be made to determine just why such a condition exists, but a few remarks concerning the true function of the laboratory in teaching engineering subjects and a brief consideration of the subject of laboratory notes and reports will serve to throw some light on the matter.

The Function of Laboratory Practice.

The main purpose in laboratory instruction as in any kind of teaching should be to make the student think; not only to comprehend the knowledge which is put before him but also to think for himself, to plan, to reason, and to judge. Laboratory practice should be given to make clearer to the student what he learns only partially from books, but it should also give much training in the ability to observe and record facts accurately and to draw correct conclusions. Another and an important purpose is to give such training and facility in doing various kinds of engineering work that the student will be able to secure employment upon graduation. This last purpose may easily be emphasized too much as, for example, when it is attempted in the field work of surveying to make the student an expert instrumentman. The engineering college is not the place to give much practice in engineering work. The college must not expect to turn out trained engineers but trained men who

who are prepared to learn readily the practice of engineering.

In order that the student shall work intelligently in the laboratory there must be a proper coordination of class room and laboratory instruction.. The teacher in the latter must not attempt to give work which is in advance of the student's knowledge of theory. Otherwise he will have to spend too much time in explanation of the nature and the purpose of the work to be done and will have to give rules containing no meaning to the student, for working up the results.. Much of the value of laboratory work as a means of training may easily be lost by leaving little or nothing to the student in the way of planning the experiment or devising the means for carrying it out.. There is too much of the kind of laboratory instruction in which the experimenter is told just what to use, just how to use it, just what results to get, and just how to work up the data.

Laboratory Notes.

One of the most valuable things which the laboratory practice should give is the ability to make an accurate, complete, and intelligible record of facts. To the end that this ability may be acquired, the student should depend largely upon his own resources in making his record of observed facts. The practice of giving forms for making records in which little more is required than filling in the blank spaces as indicated on the form is to be condemned as poor teaching. A few forms may well be given at first in some kinds of work to show good methods of practice and to establish a standard, but the student should not be deprived of the training which comes from planning his own kind of record, just because it makes easier work for the instructor. The importance of

making the original notes carefully and systematically should be taught continually. The original record is the only record and it should always be given much attention.

The practice of having the original notes taken on a loose leaf of standard size or form and attached to the final report has some very commendable features. Recording observations on loose scraps of paper or on a back leaf of the notebook and then copying them later for the permanent record is the tendency of many untrained observers, and should never be permitted. The student must learn that there is no record but the original notes. Erasures in the values which are the records of observations should not be permitted. Values which are found wrong may be crossed out neatly and the correct observed values inserted in the record. Students should be held to making their notes complete, so that any engineer acquainted with the kind of work done could use the record without additions or verbal explanation. Neatness is very desirable, but it is not to be compared in importance to completeness, accuracy, and intelligibility.

Some laboratory teachers believe that the use of a permanent, well-made notebook without detachable leaves, similar to the surveying notebooks but having special ruling suitable for laboratory records, is very desirable. The property interest in such a notebook is said to stimulate pride in the keeping of good notes. Very likely the use of permanent notebooks is sometimes best, but the loose leaf method has the one great advantage that the original record can be more conveniently and regularly inspected by the instructor. Whatever method is used, much stress should be laid upon the proper recording of the original notes. The exact form to be used is un-

important, but the ability to keep notes in some systematic, intelligible form is very desirable and should be cultivated by allowing the student to devise the form to be used.

Laboratory Reports.

Laboratory reports which consist chiefly of a page of data and results properly entered in the blank spaces designated have but little pedagogical value. They make easy work for the instructor but are of little service in training the student. Reports in which it is required to give a statement of the object of the experiment and a description of the apparatus and method used, illustrated by carefully drawn diagrams, are a grievous burden to the student, requiring an amount of work out of all proportion to the benefit received. It is a very common fault in laboratory courses that the making up of reports requires too much time spent in writing and drawing. Full descriptions are valuable as exercises in English composition if properly written, but it is not one of the main functions of the laboratory work to give training in the writing of descriptions. In most cases all that should be required is a report which gives completely, intelligibly, and concisely all that an engineer acquainted with the nature of the work would care to know. Little or no descriptive matter should be required. What is needed is a title stating the kind of work done, the date, the observers, the equipment, the data, and the results. The student should make out his report in a condensed form of his own devising, when practicable, after some instruction concerning what constitutes a good report. By criticizing the reports individually with the writers and by requiring them to make corrections or additions, the instructor can develop in a few months a considerable ability and independence

in such matters. The instructor should not seek to impress his own preferences or methods unduly. Many questions which are matters of opinion or judgment will arise, and the student's judgment should not be condemned unless it is clearly wrong. Definiteness and completeness in essential points regarding such things as column neadings, units, etc., should be insisted upon. Data and results may well be tabulated separately, for the results should stand out clearly so as to be easily found. The formula used and a sample computation by which the results are obtained might well be given but would often not be essential.

In many kinds of experiments , the calculated results should be platted and the mean results represented by a graph. When a graph is used the page containing it should be complete in itself, that is, it should have a title and sufficient statement of the apparatus, dimensions, units, etc., to make the graph intelligible and useful when detached from the rest of the report.

After the computations are made and the results tabulated or platted, the student ought to study them to see how they agree with each other and with theoretical values, and to explain if possible any marked discrepancy. The drawing of conclusions is one of the most valuable features of laboratory work, but the instructor finds that it is very difficult to get the student to make a critical study of his results and draw conclusions. Giving a number of definite questions to answer is not very satisfactory for it does not leave the student to his own judgment sufficiently in the matter of criticizing and interpreting his results. It is probably better to keep trying to draw out intelligent discussion as a conclusion to the report even though the results of the attempt may not be wholly satisfactory.

Even with laboratory reports condensed and descriptive matter reduced to a minimum, there often remains a large amount of tedious work in computing and tabulating the results. There are usually some students who avoid this drudgery by copying the work of others. It would be very desirable to have all the computations made during the laboratory period under the instructor's supervision. Each student could be given a part of the computations to perform when there are many of one kind. The results could be platted as soon as found, and mistakes could quickly be detected. In this way the instructor could make sure of each student performing the computations and could correct poor methods of doing such work. This plan will often not be practicable under present conditions, but some such method is desirable to reduce the amount of drudgery in working up laboratory reports and the evils due to the shirking of work upon the part of the lazy members of the class.

The problem of dealing with delinquent reports is one which causes much vexation. When a student is given a week in which to prepare a laboratory report, it would seem that no injustice would be done if such reports are heavily discounted for lateness and not counted at all for credit when more than a week late. If such a course is not considered advisable, an excellent plan is to refuse the student the privilege of working in the laboratory when two or more reports are delinquent. This plan has been found very effective in dealing with those students who are inclined to be very dilatory in such matters. Lateness in handing in laboratory reports or any other kind of written work should always be discouraged, and almost the only way is to refuse full credit for any work which is not handed in promptly.

4. THE INDIVIDUAL METHOD.

The individual method in teaching engineering subjects is one which, if adopted generally, would revolutionize the present scheme entirely. This method, in brief, involves the abolishing of the class as it exists at present. The student takes up each subject separately, doing all his studying, computing, drawing, etc., under the instructor's immediate supervision. He puts in all his working time each day on one subject or at most two, until the required work is completed. No lessons are assigned, but each student proceeds as rapidly as his ability will permit. As soon as one study is completed another is taken up, so a bright student may be able to finish the year's work one or two months early or he may take more than the regular work. On the other hand, the dull or slow student may have to spend more than four school years in completing the course.

Several marked advantages over other kinds of instruction are claimed for the individual method. As a means of acquainting the instructor with the personal limitations of the student and enabling him to give the best kind of teaching, namely, instruction as to how to work efficiently, such a plan is probably the best that is known. It is said by those who have tried it that the use of this method enables some students who are very slow in getting a grasp of a subject at the beginning to take hold finally and to carry the work with credit; these same students, with the ordinary class room methods, would have fallen so hopelessly behind that they could not have passed in the subject. Not only are the very slow ones helped by this method but also those who are more able than the average are benefitted in that they are not held back by the limitations of the

average student as is often the case under the usual methods.

Most authorities, while they recognize the fact of a wide range in individual differences in students, still continue to hold to the usual class room methods, finding enough or more than enough advantages in them to offset the peculiar advantages of the individual method. They believe that students receive much from their fellows in the way of knowledge and training in the class room association, which should not be sacrificed. It is also pretty generally believed that young students can not wisely be kept at one kind of work for long periods of time; that variety to a limited extent is necessary. Moreover, the practical difficulties in the way, such as are found in the irregular changing from one subject to another, in the securing of funds for employing the greater number of instructors necessary, and others of a similar character make the general adoption of such a plan seem impracticable.

In some kinds of work, such as drawing and design, several features of the individual method are already largely used. Although this method may not be practicable in all respects, its main principle, that different students have different capacities and difficulties, is well recognized in any good method of teaching. To the extent that each student's mind with its peculiar difficulties is considered a separate problem for the instructor to deal with, the individual method should always be used. Some reform of our present system of education seems to be very desirable. Provision ought to be made for teaching the student how to study and work most efficiently by having him do a large part of his studying and working under the immediate supervision of an instructor.

V. EXAMINATIONS.

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1. FUNCTIONS OF FINAL EXAMINATIONS.

Much has been said and written concerning the desirability and usefulness of examinations, and there has been almost as much variety of opinion as quantity of discussion. Most teachers agree as to the desirability of occasional examinations or quizzes during the school term, but there are not a few who disapprove of final examinations. Concerning the latter there is a wide range of opinion. Some teachers consider them a positive evil; many find them merely a practical necessity more or less undesirable; while others see in final examinations not merely a pedagogic necessity but also a positive benefit to the student in the way of training. The reason for this wide variance in opinion is found partly in the difference in character of the subjects and the difference in the methods used. What one teacher finds true from his own observation may not be true under other conditions. The result is that judgment is given after a too limited observation and without an unprejudiced study of the subject. Another reason for the widely varying positions taken among educators in the engineering colleges is found in the fact that some of them, although trained men, are trained much in engineering and little in pedagogy. The subject of examinations is a matter of pedagogy, and some knowledge of this science as well as extended observation is necessary for an intelligent judgment as to the usefulness of examinations.

There are doubtless some evils connected with final examinations. Some of them, however, should be attributed to defect-

ive methods of teaching and not to the examinations. Most of the other evils are due to a wrong way of handling examinations on the part of both instructors and students. There are good points as well as some evils, and the question becomes merely this: "Does the good in final examinations outweigh the evil, and if so, is it sufficient to warrant holding such examinations?" A majority of the teachers of engineering undoubtedly believes that the good does outweigh the evil, although different ones advance different reasons for their belief. In a recent inquiry as to the general practice in these matters, it was found that of twenty-one of the leading engineering colleges of this country, sixteen have final examinations as a matter of university regulations, four hold or dispense with them according to departmental policy, while one prohibits their use entirely. The principal uses for final examinations, which will hereafter be called merely examinations, are given below.

1. Examinations furnish the instructor a means of gaging the student's attainment. By many, this is considered the chief, if not the only, use which makes it worth while to give examinations. It is evident that their usefulness for this purpose depends largely upon the size of the class and the method of teaching used. In subjects taught by the lecture method, supplemented with little quiz or recitation work, final examinations are necessary; whereas frequent recitations make the examination of little use to the instructor. In subjects involving a large amount of problem work along with the recitations, aid of this sort is often entirely unnecessary in determining the standing of the student. Between the extremes of conditions here mentioned are various intermediate sets of conditions which give this use of the examination varying

degrees of importance in the opinion of the instructor.

2. Examinations tend to cause more diligent and connected study during the term than would be made without them. The opposite of this is sometimes said to be true and is advanced as one of the chief evils of examinations. It is said that students will often neglect their work during the term, depending upon "cramming" for a few days at the last. It is wrong, however, to attribute to the examination the evils of cramming, for these evils when they exist, are due to defective methods of teaching the subject. It is a very simple matter to discourage the practice of cramming and make it of little use by requiring reasonably good work throughout the term, provided there is a sufficient number of recitations and quizzes. When insufficient opportunity for checking up the student's work during the term is provided, the evils of cramming are made possible, but they are due then to the faulty system of instruction. It may safely be said that the more the teacher needs the examination as a means for determining the student's standing, the poorer is his method of instruction. With only due emphasis and weight given to the examination and with good methods of instruction, there will be little of the cramming evil. On the other hand, if the student knows that he will be required to show a reasonable knowledge of the whole subject at the end of the term, his studying will likely be more thorough than if no examination is held. He will try harder to fix firmly in mind the important parts of the subject, knowing that he must do so in order to write a creditable paper.

3. The thorough review just before the examination is useful for giving a more comprehensive grasp of the subject than would

be obtained without such a review. The force of this argument clearly depends very much upon the manner in which the review is made. The comprehensive grasp obtained by the average student under ordinary conditions is very likely a negligible quantity, existing more in the imagination of the theorist than in actual fact. Often the special preparation or review consists in storing away in the memory as many facts and formulas as possible, without much regard to their relations to each other or to anything else. The fault lies in the teaching. If examinations were more carefully planned to encourage a systematic and connected review, and if students were taught how to make such a review, the benefits would become real and important instead of being as they often are, very largely imaginary.

Much depends upon the kind of examinations to which the student is accustomed. Since his past examinations have often not been of the kind to train his judgment properly concerning the kind of preparation to make, it is not well to leave him in the dark as to the nature of the examination to be given. On the other hand, the instructor should guard against leaving nothing to the student's own judgment in deciding what to study in reviewing the subject. By judicious counsel in this matter the student is helped to secure a more complete view of the subject than he will obtain from the daily study of more or less isolated parts or from partial reviews only, during the term. It is difficult to know much as to the amount of good of this kind that comes from final examinations, but many experienced teachers believe that the benefits of the final review are sufficient to furnish a very strong argument in favor of such examinations.

4. The examination gives a training in the power to work under pressure of difficulties and limited time. The power of self-control and of concentration of effort is said to be developed under stress of having to make a creditable showing of knowledge in the examination. Students themselves recognize the value of this power at such times, as is shown frequently by the remarks of those who have done poorly that they "went to pieces" or "got rattled". With all due allowance for the fact that these students are often unable to diagnose their cases correctly, it is doubtless true that there is often a tendency to "get rattled" and that this weakness of "going to pieces" is sometimes the cause of a failure in the examination. This being true, the power of self-control and concentration is needed in examinations, and is therefore considerably developed by being occasionally called into use through such tests. Situations in life after graduation often call for the exercise of the same power, and since the final examination tends to give strength and training along this line, one more argument is found in its favor.

The arguments against final examinations will now be briefly considered. Probably the most valid argument is that such examinations take up too much valuable time. If they are viewed merely as a means of gaging the student's attainment, the charge is doubtless true. It has been shown, however, that this should be considered a subordinate function, as it will be when good methods of instruction are used. The question as to whether the benefits to the student, of examinations properly given, are worth the time spent upon them must remain largely a matter of opinion.

The evil effects of a system which permits a student

to pass, by means of "cramming", in a subject of which he has no adequate knowledge are sometimes charged against the final examinations. It has been shown that such evil effects are not chargeable to the examination but to the wrong system of instruction which makes the examination the main or only test of passing.

It is held by some that final examinations bring too great a mental and physical strain upon the student. No doubt the charge is sometimes true if the final examination is all and the term's work nothing except as shown in the examination. It is not true when due weight is given to the term's work from day to day, so that the final examination need be neither so hard nor so important that an unreasonable amount of effort in preparing for it is encouraged. A proper method of teaching the subject and a proper amount of instruction concerning the examination will usually remove any tendency to bring on nervous prostration by too much hard study.

2. FUNCTIONS OF WRITTEN QUIZZES.

Much of what has been said concerning the desirability and usefulness of final examinations will apply also to written quizzes, which are merely shorter and less formal examinations held occasionally during the term. Such quizzes are generally believed to be more useful and necessary in a good system of instruction than the final examination. Their most practical uses are, to hold the student to diligent study during the term, to furnish the instructor a more definite knowledge of the student's attainment and personal difficulties than can be had from the usual class room recitation only, and to show to the student his own deficiencies. Only the last named use needs any further discussion here.

It is a well known fact that students who are not doing well often believe they are doing good work until they learn differ-

ently upon being required to show their knowledge in a written quiz. Even then some of them do not realize their deficiencies until the marked papers, with grades which indicate the instructor's estimate of their value, are returned to them. Something worth while has been accomplished when the student is thus shown wherein he has made mistakes and in what respects he needs to improve his work. A short discussion before the class, of the more common errors made in the quiz will be found useful in correcting erroneous ideas. The benefit which the student receives from the mere return of his marked paper depends upon his ability and desire to see his mistakes and to know the cause and remedy. The students who need it the most will usually get the least benefit, and the average students will get much less than they would if something more is done than merely returning their marked quiz papers. It is not enough for the instructor to tell them to look over their papers carefully to note the criticisms and to make corrections. Those who need this counsel the most will usually heed it the least. Requiring the papers to be corrected and handed in again is a considerable improvement but is not entirely satisfactory. The best procedure, when practicable, is to discuss each student's paper with him individually, pointing out not only his mistakes but also the probable causes and specific remedies. Here is an opportunity for some very effective teaching. There are many causes for poor work besides lack of study, which can often be removed when recognized if the proper remedy is suggested. Many students do not know how to study properly; many do not appreciate the importance of neatness, system, and accuracy, or do not recognize their own lack in these things. They need direct personal counsel and the instructor is the one to

give it to them.

The written quiz furnishes an excellent opportunity for giving individual instruction of the most valuable kind. To be most effective, such instruction should begin early in the term so it is desirable to give quizzes early in order to get acquainted with each student's peculiar failings as soon as possible. Though it may not be practicable to have a personal consultation with each member of the class after each quiz, it is surely practicable and desirable to call in those who most need help or warning. Used thus as a means of enabling the instructor to give valuable individual instruction as needed, the written quiz becomes a very important device in the machinery of technical education.

3. METHODS OF CONDUCTING EXAMINATIONS .

The manner of conducting examinations is important chiefly in its relation to the prevention of fraud. The fact that there is likely to be fraud in examinations, although unpleasant to contemplate, is one which can not safely be ignored by any teacher. The matter is important first, because the instructor should not allow himself to be mislead concerning his students' attainments, lest he permit those to pass who do not deserve it, but it is important still more on account of the moral questions involved. As in other matters relating to teaching, the primary consideration should be the student's welfare, not the instructor's convenience, and it may be stated as a general proposition that examinations and quizzes should not be conducted in such a manner as to tend to lower the standard of morals.

There are two extreme positions taken in regard to dealing with the matter of fraud in examinations, besides various positions

lying intermediate between them. One of these extremes is embodied in the so-called honor system. Under this system the students are placed upon their honor; they give pledges not to give or receive help in examinations, and they assume all responsibility in the matter of detecting and punishing cases of fraud. The instructor is present during the examination, chiefly for the purpose of preserving order and answering proper questions. It is said that where the honor system is used, very few cases of cheating occur, both on account of the opprobrium which attaches to cheating when discovered and reported by fellow students, and by reason of the high sense of honor which is developed under this system. The honor system is used generally in the South but has not been adopted by many of the northern universities. The other extreme is found in the use of the proctor system, in which a number of watchers or proctors are detailed to be on watch constantly to prevent and detect cheating. This system is not much used. In fact, the leading engineering schools do not, as a rule, have any definite system as exemplified in the two extremes noted above. The manner of conducting the examinations is usually a matter of departmental regulations or is left to the discretion of the instructor, who then chooses a method which usually lies intermediate between the honor system and the proctor system.

Without entering into the question of the merits of the two systems described, it is safe to say that any instructor will probably not find it wise to adopt either one of them when such a course is not in accordance with the general custom of the college. This is especially true as to the honor system, which depends for its success upon its being indorsed and upheld by general student

sentiment. Where the standards and restraints of this system do not prevail generally throughout the college or university, it is not likely that one instructor can bring them to prevail in his own particular course. On the other hand, it is unwise to go to the other extreme and give the students reason to believe that they are suspected and are being constantly watched. Such a course, when used where it is not general, is likely to cause resentment on the part of the honest students and to incite some to cheat just to outwit the instructor. Where neither system is in general use neither extreme should be taken. Under such circumstances, let the instructor impress as strongly as possible upon his students the importance of self-reliance and honesty in school matters. Let him dwell upon the high ethical standards which have in the past distinguished the engineering profession, and let him show that such standards are not established by dishonest practices in school life. Let him do all in his power to cultivate a high standard of morals, and then let him so conduct his examinations that there shall be a minimum of opportunity and temptation for cheating. Let him assume every student to be honest until reasons appear for believing otherwise, and let him then make it easy to be honest rather than easy to be dishonest. Such a course is the most reasonable one to pursue and will usually be found the most satisfactory.

Various means for reducing temptation and opportunity for cheating in examinations, which will apply to a large extent in the conducting of written quizzes, are used and recommended by those who have given study to the problem. The reasons underlying the methods which follow are obvious in some cases and will not need any extended discussion.

1. The questions to be answered should be given by means of type-written or similar copies placed in the hands of each student, not written on the blackboard before or during the examination as is often done. Besides lessening the chances for cheating, this method saves time for the student and reduces the number of mistakes and omissions made in giving and reading the questions.

2. Two or more sets of questions should be used when practicable, in order that those in adjacent seats shall not have the same questions. This is especially desirable when it is necessary to seat the students close together. It is sometimes almost impossible for a student to keep from seeing his neighbor's work, but if the questions require his own work to be different, the opportunities for cheating are largely removed.

3. The questions should be of such a kind that a glance at a neighbor's paper can not give much clue to the answers, especially when only one set of questions is used. They should not be so simple that a mere glimpse of a sketch or a formula will be sufficient to give much help. This not only helps to prevent fraud, but it also helps those who would not think of cheating, to avoid being influenced by an unintentional glimpse of another's paper.

4. In questions involving solutions of problems, the processes by which the results are obtained should be required to be shown as well as the results themselves.

5. The answers to questions and all computations should be written in examination books furnished and stamped by the department, and the use of any other paper should be prohibited; also the tearing of leaves from the examination book should not be allowed. If loose sheets of paper are used, as is ordinarily the case in written quizzes, the student should not be permitted to leave them lying

face upwards where they can be seen easily by others.

6. The instructor should remain in the room, and should not busy himself with any work other than that of conducting the examination. The practice of sitting at a desk reading or correcting papers, which is followed by some instructors, makes cheating easy and is to be condemned. On the other hand, it is not advisable to make the students feel that they are being constantly watched. The most reasonable procedure consists in acting in such a manner that cheating will not be easy, at the same time avoiding giving the impression that attempts at cheating are expected. In fact, the instructor himself should take the view that cheating is the exception rather than the rule, and his aim should be to prevent cheating rather than to detect it.

If the above precautions are used there will be little trouble from the more common kind of cheating, which consists in the obtaining of help from other students during the examination. Such cheating is often unpremeditated, and it would often not occur but for the ease with which it can be done. Some students, in fear of failure, are unable to withstand the temptation to secure help so easily within reach under the lax methods often used. It is unwise to put this temptation in the way of students, and the instructor who takes such means as those described for minimizing the opportunity and temptation to cheat is doing no more than his duty. The other kind of cheating, which is premeditated, involves the preparation and use of written notes commonly called a "pony". The way to prevent cheating of this kind, in addition to the means already described, consists in making the questions, in so far as practicable, of such a kind that a "pony" is of little or no use.

4. KINDS OF EXAMINATIONS.

Examinations may be classified, as to kind, under two distinct heads: (1) those in which the student is required to write from his general knowledge of the subject, without the aid of text-books or notes; (2) those in which the student is allowed to bring to class and use whatever books and notes he may desire. One kind is largely a test of ability, requiring but little tax on the memory; the other is ordinarily, to a large extent, a test of the memory, but it may and should be a test of ability as well. A few teachers have tried the plan of allowing the student full access to notes and references, and they have expressed themselves as being well pleased with the results. The applicability of such a plan must depend largely upon the nature of the subject which is being taught. In those subjects in which the work consists largely in the application of fundamental principles and mathematics to numerical problems, the use of text-books and notes in the examination would relieve the student from burdening his memory with formulas and rules, and would allow him to show what he can accomplish. A strong argument in favor of this plan is that the examination then approaches closely the ordinary situation in professional life, in which the engineer has free access to books when a difficult problem confronts him. The examination is thus made a test of the student's practical ability to make use of books and get correct results under the ordinary conditions of an engineer's work. Some subjects, however, which are largely informational in character, are not suited to this sort of examination. There are many facts and fundamental principles which the engineering graduate should

know, and some of the examinations may well be designed to require a broad knowledge of principles and facts, and some independence of books.

Each of the two kinds of examinations lacks something which the other supplies. A combination of the two, when practicable, would be desirable. Such a combination has been tried with good results, two sets of questions being used. When the class is large, and only two or three hours given to the examination, this combination may not be practicable. If such be the case, the more satisfactory plan will usually be to prohibit the use of text-books or other help in the examination.

5. KINDS OF QUESTIONS.

The ability to make out a good set of examination questions is not possessed by some instructors, or at least it is not exercised by them. To prepare a well balanced set of questions requires a considerable amount of time and thoughtful consideration; too often these are not given to the work sufficiently, with the result that often examinations do not serve as fully as they might the purposes for which they are given.

When the character of the subject permits, the set of questions should be made up of the following kinds: 1. Questions involving a knowledge of definitions, fundamental principles, theory, etc. 2. Questions involving analytical treatment of general problems. 3. Questions requiring the solution of numerical problems. 4. Questions concerning facts of observation, methods of engineering practice, etc. Often an instructor will fail to make a properly balanced set of questions merely because of a lack of consideration of the subject. Some kinds of questions are much

more easily corrected or marked than others, and this fact causes a tendency to choose those kinds and omit the kind which is harder to correct. The convenience of the instructor should not be the ruling consideration in choosing the questions. To be most fair to all the students, the questions should be well distributed among the several kinds, and the instructor's convenience should not be allowed to stand in the way of making the examination the most desirable kind of a test.

The average student can not be expected to know at the end of the term all that has been covered in the recitations or lectures. The questions therefore should involve a knowledge of only those things which are essential to a fair grasp of the subject. The asking of questions on obscure and unimportant points shows poor judgment or thoughtlessness on the part of the teacher. If the student knows that the questions are to be on the essential or important things, he will not try to cram into his mind all that he has studied during the term, but will proceed to exercise his judgment in deciding what are the important parts, and will thereby gain more of that comprehensive grasp of the subject which the right kind of examination tends to give.

Questions should not be such that they can be answered entirely or chiefly by the aid of the memory alone. Such questions neither furnish a reliable measure of the student's real knowledge nor tend to encourage the right kind of study. If definitions or formulas are asked, let the student be required to show his understanding of their meaning by giving illustrations or applications.

Much care is needed in the wording of the questions in order to make the meaning clear. Phrases with ambiguous meaning

should be carefully looked for and revised. Technical words and phrases which have been used rarely in the class room should not be used in examination questions. The instructor should use his words with discrimination and should endeavor at all suitable times to teach his students to discriminate between words of somewhat similar meaning. There will then be less misunderstanding of what is required when such words as state, describe, explain, and deduce are used. Students often ask for an oral interpretation of a question, sometimes on account of a faulty statement of the question, and sometimes in order to get a clue as to the answer. It is not wise to give any further statement of the question, providing that it has been carefully and correctly given on the examination paper. The instructor is likely to tell more than he intends or thinks, and to give some students an advantage over the others who do not seek such help.

The use of questions in which the student is asked to "discuss briefly" or merely to "discuss" some topic has not been found advisable, especially for the younger students and also when an important function of the examination is to furnish help in deciding whether a student is to pass or fail. Such questions are not explicit enough to secure a good discussion from most students, even though they may know many of the points which ought to be brought out. A question of this kind will almost invariably bring unsatisfactory answers, and those whose passing is doubtful will usually be able to write little or no intelligent discussion.

Problems should be such as to require more than merely substituting in a formula the data which ~~is~~ are given. To be sure, there may be some thinking required to understand the data and to use the

formula correctly. The idea here is that the problem should involve some real thinking on the part of the student, and that usually something more than mere substitution in a formula is necessary. The problem will usually have to be simple or somewhat similar to those which have been solved during the term, for the student is not able, in the limited time given to each question, to analyze and solve a problem which is very different from those which he has already had. A short problem with data which will make the computations easy, will usually serve the purpose as well as a longer one containing numbers which make the computations tedious. An inexperienced teacher is likely to give too much work for the time allowed in the examination, and there is usually a tendency to make the problems too hard from fear of making them too easy.

After the questions are all prepared, the instructor should write answers to all of them in just the way he would wish the student to answer them. He should keep a record of the time required, and if he finds that he can write the whole paper in one half or one third of the time allowed to the student, the examination is of about the right length. This plan serves also to point out errors and desirable changes in the questions. Moreover, it is no inconsiderable help to the instructor, when the time comes for grading the examination papers, to have put himself in the student's place by writing the answers to the questions.

6. GRADING EXAMINATION PAPERS.

In order to grade all the papers by the same standard, the instructor should read and grade all the answers to one question at a time. If all the work in each paper is graded before another paper is taken up, there is much chance for changing the standard

of marking, between the reading of the first and last papers. The reader may be either more lenient or more severe in his marking towards the last, the change depending upon his state of fatigue and upon the quality of the work shown in the papers that have already been read. Experience shows that the grading is likely to be more uniform when one question is marked in all the books before another question is begun. A decided econory of effort also results, since the mind is not required to consider a wide range of ideas in rapid succession, as when passing continually from one question to another.

The instructor should purposely refrain from seeing the student's names on the papers, until all the questions have been graded. Even though he may think himself entirely free from prejudice, he is very likely to be influenced in his marking by the personality of the student, if he knows whose paper he is grading. Those who have yet to try this plan will be surprised by the results in some cases. There is a tendency to discount the unexpectedly good work of a poor student, and to be lenient when a good student does poorly, if the writer of the paper is known.

When the grading is done on a basis of 100 for perfect it is best to mark each question on a basis of 10 for perfect, even though there may not be ten questions. Then if 60 or 70 is the minimum passing grade, it is easier to mark each question properly in accordance with that grade than if each question is marked 14 2/7 or 16 2/3 for perfect, as when seven or six questions are used. After all the questions are graded, the average grade can quickly be found by adding the several grades, multiplying by ten, and dividing by the number of questions. Of course, when different weights are given to different questions, this plan will not be a plicable.

VI.. PROFICIENCY REQUIRED FOR PASSING.

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After the teacher has done all he reasonably can to instruct and train his students, there still remains for him a task of much responsibility, to pass judgment upon their attainments. Whether a student's work is to be marked 92 or 88 on the term's work is of relatively small importance, but whether he is to be marked "passed" or "failed" is a very important question.. There will usually be the recorded grades in quizzes, problems, recitations, etc., besides the examination grades to consider. Obviously there can be no way of determining in percent just how nearly correct is the solution of a problem or the answer to a question when it is not entirely correct. All grades are merely approximate measures of the worth of the student's work as judged by the instructor, the basis for his judgment being a grade of 100 for perfect and 70, perhaps, for barely passing.. Whether 60 or 70 or 75 be the minimum passing grade is of little importance; the grades will be determined with reference to the passing grade and not by the actual percentage of correct work, which of course can not be measured. Averaging a number of grades in different kinds of work, to determine a final grade, does not relieve the instructor from the responsibility, in some cases, of deciding whether the student passes or fails. The recorded grades are valuable chiefly in guiding the judgment as to the student's standing, and the calculated average grade should not be the deciding factor in doubtful cases. The question whether a student is to pass or fail should be decided on its merits, and the decision may sometimes properly be contrary to

what an average grade would indicate. Not many teachers would think of giving as the reason for reporting a failure, the fact that the final average of the student's grades was 69, when a grade of 70 was required for passing, yet that sort of thing is sometimes done. It is not usually considered good policy to report a grade of 69, under the above circumstances, if the student is not to be passed; a grade of 65 perhaps should be reported in order that the impression may not be given the student that the failure was given merely because of the slight deficiency in his final grade. The instructor owes it to himself and to the student to pass careful final judgment upon any doubtful case, basing his decision chiefly upon the answer to the question whether the student has learned enough of the subject to entitle him to proceed. Sometimes other considerations must be taken into account, as the failure to perform required work in drawing, problems, etc.

Clearly no definite rule can be given which will determine what degree of proficiency should be required for a passing grade. The instructor will have to decide each case according to his judgment. If he finds that the student has a fair knowledge of the essentials of the subject and that he has been fairly diligent in performing the required work, a passing grade may properly be given, even though much of the work has not been satisfactory, and many things forgotten which the student ought to know. The beginner in teaching is almost always surprised and discouraged at the end of the year to find how much his students do not know. He usually expects too much in the way of accomplishment by the immature young men in his charge. But if he has been faithful in his own work he will be able to see much that has been accomplished in the

way of development and training. Let him consider what the student does know and has learned to do, and he will find cause to feel that his efforts have not been in vain.

Frequently there will be one or more in a class who seem wholly incompetent to do the required work, and occasionally one who is very careless and indifferent. In such cases, every reasonable effort should be made early to know these men thoroughly. Patience should be used with those who are seemingly incompetent, though earnest; plain speaking with the lazy and indifferent; and good counsel with both. If, after due inquiry and effort, it is found impossible to get these students into line, they must be left to fall behind and fail. It is mistaken kindness to allow any to proceed who are wholly unfitted and incompetent.

A teacher who has the best interests of his students at heart will sometimes be able to transfer the seemingly incompetent or indifferent one to the ranks of those who are doing diligent and creditable work. He need not make of his class room a retreat for the mentally halt and blind, nor need he plead with his students to get them to work; but a word of encouragement or a bit of good counsel which inquiry and sympathy may make possible, will often be of great help to the one who is not keeping up, when an exacting or indifferent attitude would only assist in making him fall farther behind. The best teacher is the one who not only uses the best methods of teaching, but also has an active human interest in each one of his students and makes that interest felt.

VII. CONCLUSION.

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In the foregoing pages the purpose of engineering education has been outlined, and the principal methods used in teaching engineering subjects have been briefly discussed. Few thoughtful teachers will dispute the position that the main purpose of engineering education is the development of the powers of the understanding. Concerning the merits of the various methods discussed, some difference of opinion may reasonably be expected. However, since most of the methods advocated have been found good in practice, either by the writer or by others whose experience has been more extended, they will doubtless commend themselves to the instructor who is considering how best to perform his work of teaching engineering. That careful consideration should be given to the details of the instruction work can not be doubted. A very few there may be who can choose instinctively the best means for instructing and training their students, with little or no consideration of the various methods which might be used, just as there are a few able teachers who can safely use class room methods which, in the general experience, have been found unwise. Most of us are not teachers of this exceptional ability. We need to apply to our problems of teaching the same scientific spirit which we apply to the problems of engineering in order that we may find out and use the methods which will give the best results. Thoughtful observation on the part of the instructor and a study of the experience of others furnish the means for finding out what methods to use. Although this paper is not exhaustive in presenting the results of experience in teaching engineering subjects, it is hoped that some helpful suggestions have

been found in it by the instructor seeking for information along this line. If what has been presented serves only to arouse an appreciation of the importance of using systematic methods in teaching, the writer will feel that a good and sufficient purpose has been accomplished.

UNIVERSITY OF ILLINOIS-URBANA
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